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Agricultural Memorandum No. 976 R. Barrowcliffe

# The Relationship between Rainfall and Height

## Introduction

This short memorandum shows the results of a simple study into this complicated subject, which was carried out as part of a larger piece of work on Agricultural Land Classification. This will be the subject of a future Memorandum.

In the interests of short-term expediency and necessity, the treatment is neither rigorous nor exhaustive. However, it is felt that any increase in accuracy that could be achieved would demand a disproportionate amount of effort. To determine the exact relation would require the order of a years work, as opposed to the few days taken for this study.

## Investigations:

A glance at a map of Britain's rainfall, with topography superimposed, will quickly reveal that there is some link between the amount of rainfall and the height above sea-level at a given point. Further inspection will show that there is also an east-west trend; with the greatest amounts in the west. On a similar theme, it is the western slopes of mountainous regions that receive most rainfall as a general rule, with rain "shadows" occurring in the east.

All of this is simply a reflection of the fact that the majority of rain in this country is a consequence of fronts moving from west to east, or south-west to the north-east. Most of their impact is felt in the west and south-west, because by the time they reach the east they can be a 'spent force'. Also, the mountainous regions in the west will promote extra rainfall by forcing mass ascent, or by some other enhancement mechanism.

Bleasdale and Chan (1972) attempted to show that there was a simple linear relationship between average annual rainfall, R, and height, H, for the whole country. This was of the form,

$$R = a + bH,$$

where a was found to be 700 mm, and b was likewise determined as 2.5 mm $m^{-1}$. R is in mm, and H in m.

This is reasonable enough as a general expression for the entire country, but it does produce significant anomalies in many regions. For example, near sea-level in parts of East Anglia the average annual rainfall is about 550 mm. Conversely, on the Cumbrian and Welsh coasts the average annual rainfall can be as high as 1100 mm.

Clearly then, different regions possess different values of the coefficients a and b. It would seem sensible therefore to divide the country into regions of some homogeneity in their rainfall characteristics.

This approach was taken for areas which were initially drawn up by partly by intuition and partly by hydrological areas. Data was plotted from stations listed in the RAINMASTER dataset which had a continuous record, or very nearly so, in the period 1941-1970. After this was done, it became apparent that the regions needed to be subdivided further in some cases. For instance, in Southern England, the counties of Hampshire and Sussex were found to be significantly wetter than for London, Kent and central Southern England. The areas

FHaB

were finally defined by careful study of the map of average annual rainfall, 1941-70. (Met O 886 (SB)).

The resulting plots showed a considerable degree of scatter as might be expected, particularly at the higher altitudes. Some of the plots, especially those with a wide range of heights, had an apparent 'hook' to them near sea-level, perhaps indicating the presence of a coastal effect. Alternatively, it could be that small-scale terrain features exert a disproportionate effect on rain-bearing clouds than do the medium-sized features.

Despite these slight non-linearities, the data was considered to be too crudely presented to warrant any other treatment than to simply fit a straight-line. Furthermore, it was considered to be sufficiently accurate to do this by eye. This was justified to a certain extent, in that some human subjectivity is required in order to pick out data points that belong to a distinct sub-region. For example, the Lake District stands out as being much wetter than the surrounding areas in the North-west.

Table 1: Values of the Coefficients.

| | Region | a | b |
|---|---|---|---|
| A | North-West England | 900 | 1.7 |
| B | North-East England and Yorkshire | 600 | 1.6 |
| C | The Lake District | 1100 | 2.6 |
| D | South Lancashire, Cheshire and W. Derbys. | 750 | 1.7 |
| E | South Yorks., Notts., Lincs., and N. Norfolk | 590 | 1.05 |
| F | Wales | 900 | 2.6 |
| G | Welsh Borders and West Midlands | 590 | 1.1 |
| H | East Midlands, Fens and Essex | 530 | 1.0 |
| I | South-West England | 800 | 2.25 |
| J | Central Southern England and Kent | 600 | 1.05 |
| K | Hampshire and Sussex | 700 | 1.6 |

Figure 1 shows the exact definition of these regions, and two examples are shown of the kind of data the coefficients are based

Comments:

The degree of scatter in the data is considerable enough to give a sizeable spread of values. At 100 m this could be 50-100 mm, rising to 250 mm in the mountainous areas. This scatter is due to the fact that each site will have its own particular aspect, which is normally thought to contribute something of the order of 15% - 20% towards the total rainfall.

The largest flaw in the method probably arises in areas which are on the boundary of two quite different regions in terms of their coefficients. For instance, there is a large change in the value of b when moving from the mountains of Wales to the border region. It is unrealistic to say that such a large change occurs at a specific boundary, but on the other hand, there is a practical limit to how many distinct regions can be created.

A detailed study of the problem would probably result in one 'universal' regression

formula with as many as four variables, of which h eight was the predominant one. It would not necessarily be linear. However, for the purposes for which these results were required, they are quite satisfactory.

Reference:

Bleasdale A., and Chan Y. K., (1972):

- "Orographic influences on the distribution of preceipitation".

WMO No. 326
"Distribution of precipitation in mountainous areas"
Volume II
(Geilo Symposium, Norway. 31st July - 5th August 1972).

All comments and suggestions to the author.

10th May 1982

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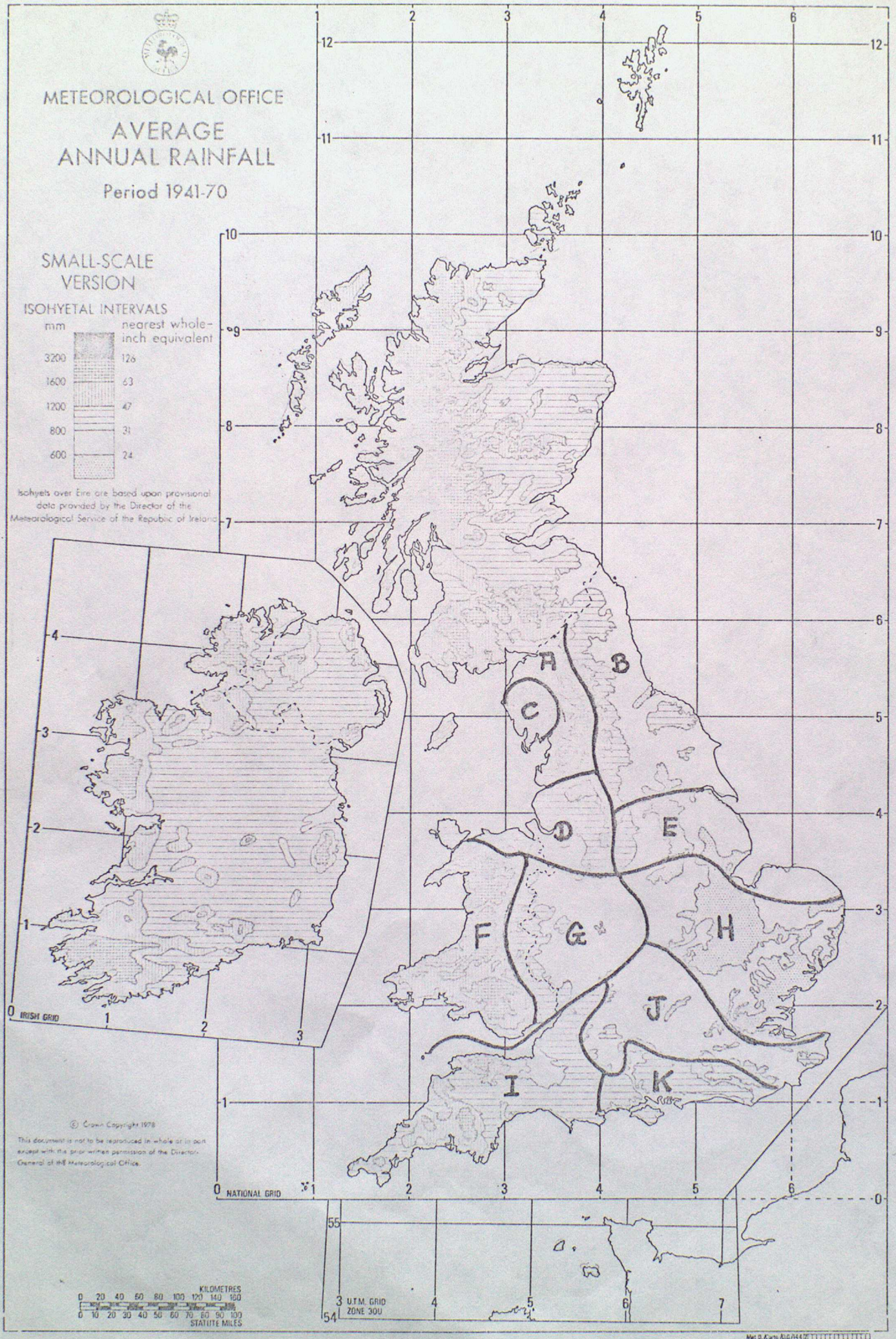
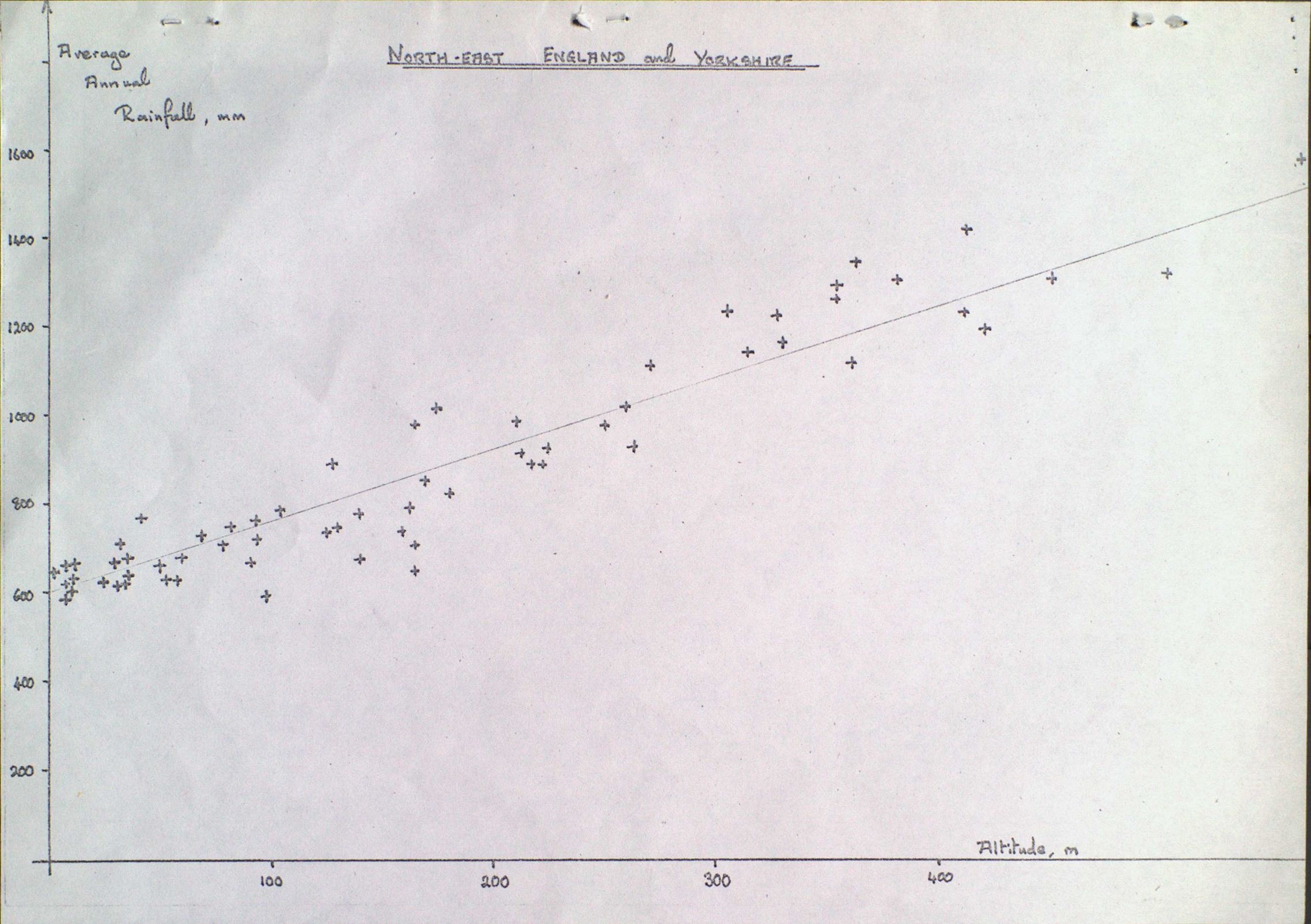
Figure 1. Rainfall Regions A-K




NORTH-EAST ENGLAND and YORKSHIRE
Average Annual Rainfall, mm
1600
1400
1200
1000
800
600
400
200
100
200
300
400
Altitude, m